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IRRIGATION AND RECLAMATION IN THE ANCIENT MEDITERRANEAN REGION*

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INTRODUCTION

The early date at which irrigation appeared in the Mediterranean lands is proof of its necessity. In Egypt it goes back to 4,000 B.C., or beyond, and in other sections of the region it is described, often minutely, in the most ancient literatures or the earliest records of ancient travelers and traders. It developed in response to condition of climate and relief, and therefore from of old it was as widespread as it is today in these same lands. It supplemented the winter rains in dry years when the tantalizing clouds held tight their burden of moisture; it saved the ripening fields of wheat and barley when late spring showers quite failed; it rendered possible all the quick-growing summer crops which required intense heat and ample moisture; and it was regularly applied with animal manures, in order to make these beneficial and not deleterious to the crops.

Furthermore, irrigation was bound up with reclamation projects designed to increase the arable area of the Mediterranean countries. It pushed forward the verdant line of vegetation into the tawny arid margin of the Mediterranean region; it was closely connected with the reclamation of wet lowlands by means of dykes and canals, for drainage ditches at proper levels were readily converted into irrigation conduits; and it became an adjunct to dams or reservoirs for flood control of mountain torrents, when these flashed into spate during winter storms and scoured the bordering fields.

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The author uses modern climatic data because the burden of evidence indicates no appreciable change in climate in historical times.

Fertile, moist alluvium, always at a premium in this region of predominant mountain relief, was found only in valley floors, small lacustrine basins, and silted coastal plains. Here the soil was best and ground water abundant, but such lands were exposed to inundation during the winter rains and spring thaws on the highlands. Where they took the form of extensive deltaic flats on low coasts, the sluggish run-off left them water-logged, fit only in their natural state for wet summer pastures. To reclaim this productive soil, the ancient farmers early adopted measures of flood control. Their first step was to build dykes for the protection of the tilled fields; the next was to divert the excess water to nearby districts needing more moisture; and the final step was to impound the flood waters of the winter for summer distribution.

Irrigation in the Mediterranean countries had therefore either the single motive of conducting water to arid lands, like the streams of Anti-Lebanon to the flowery oasis of Damascus, or the double motive of drainage and distribution. Wherever practised, it stimulated intensive tillage. Irrigable land was generally limited in extent and high in value. As an economic proposition, it had to make a return commensurate with the outlay of capital and labor expressed by the water tax.

Crops Raised by Irrigation.—The crops requiring irrigation were numerous. They included various legumes, like bean, pea, lentil, vetch, and chicken-pea, which were sown in the spring and watered when in bloom but rarely afterwards;[1] hay meadows, watered after each mowing, which usually occurred three times during the summer;[2] fodder crops, especially alfalfa or medic clover, which was harvested from four to six times annually and as often irrigated;[3] panic and millet, raised as summer crops on irrigated land, which in dry regions like lowland Cilicia and Greece was covered with a network of conduits.[4] But panic was given water in moderation, because an excess made it lose its leaves.[5]

One notes that the ancient farmers practised irrigation with caution and with economy of water, to get the best results. According to Virgil, in the Po valley water was shut off from a young meadow as soon as the grass had put forth a stem, though irrigation streams were abundant.[6] All plants accustomed to a dry soil and climate received an absolute minimum of water in summer, both in Greece and Italy. Fruit trees and deciduous shade trees, when being propagated in nursery beds, were frequently irrigated; but when mature, they were irrigated only in the intense drought

of late July and August, and then only sparingly because much water was found to injure the roots. Moreover, the amount was proportioned to the age of the trees, saplings with their scant foliage receiving less.[7] This caution in application of water may partly explain the rare mention by ancient writers of saline or alkaline accumulations on irrigated soils, though high relief and rapid drainage also contributed to this healthy condition.

The ancient Jews and Greeks regarded summer tillage and irrigation as inseparable. Homer describes the irrigation of plantations, orchards, and gardens in Ithaca and Sheria (Corfu), both islands on the rainy western side of Greece.[8] Theophrastus states that vines and pomegranates loved water and derived thence their chief nutriment;[9] but the irrigation of vineyards was generally confined to dry districts like the eastern, rain-shadow slope of the Taygetos Mountains in Laconia,[10] and the arid, over-drained soil of Palestine. Ezekiel, in his rich figurative speech, describes a vine "planted in good soil by great waters, that it might bring forth branches and that it might bear fruit."[11] Pliny mentions the irrigation of vines in the high Sulmo valley of the Central Apennines, as a method of improving the harsh flavor of the local wines;[12] but water was so abundant in the Sulmo district that grain fields also were irrigated in spring.[13]

Even olive groves were not everywhere exempt from irrigation. They yielded the best oil when cultivated by dry-farming methods; but if large fruit was the object, they were watered in mid-September to stimulate the growth of the berries.[14] But the poor limestone soil and dry climate of Attica necessitated pungent manure and moderate watering for the olive orchards.[15] The sacred grove of Pallas Athene in the Academy, which was irrigated by the parceled streams of the Cephisos River, served as a public park; its "deep impenetrable shade" lauded by Sophocles[16] indicates a dense foliage due to ample watering, for olive trees usually afford scant protection from the searching rays of the Mediterranean sun, as any one familiar with Greece well knows. It was in regions with little surplus water for irrigation, like Syria, Palestine, Cyrenaica, Attica, Sicyon, and Corinth that oil rather than fruit formed the chief product of the olive orchards.[17]

Fruit trees and shrubs from the monsoon countries of Asia and the river oases of Persia and Mesopotamia were gradually introduced along the maritime track from the Orient, as articles of commerce or prizes of the Macedonian and Roman conquests of

the Near East. Such were the apricot, peach, various plums, cherries, pomegranates, and finally the citron. These trees, which required both heat and moisture for fruition, gave fresh impulse to orchard culture by irrigation. Hence they were planted near the base of the mountains,[18] where springs broke out along old fault lines and kept the soil damp through infiltration or supplied water for irrigation. Such conditions were found along the edges of the Eurotas valley in Laconia, where the traveler today sees orange groves. Associated with these plantations were doubtless the orchards of pears and apples native to the region, but requiring mid-summer irrigation to develop the fruit.[19] Varieties of both were numerous, but the only good ones came from the cooler districts of the region. The best were raised in an Alpine village near Aquileia and exported to Rome; the next best grew near Gangra far up in the highlands of Paphlagonia.[20]

The Mediterranean region produced in spring bulbous or tuberous plants and countless herbs. Found in their native state, they were small and undeveloped, but when their growing period was prolonged into summer by artificial irrigation, they afforded an excellent and varied vegetable diet. Therefore, the well watered vegetable garden became a feature of ancient Mediterranean tillage. It was worked with the utmost care, manured and irrigated;[21] bulbs and seedlings were regularly transplanted to stimulate the growth.[22] Interculture of garlic or onion with some companion crop of legumes was practised.[23] Hardly a feature of modern intensive cultivation was omitted. The great cities of the ancient world, like Jerusalem, Thebes, Athens,[24] Alexandria, Carthage, and Rome[25] were surrounded by these truck gardens, which sent their fine produce daily to the urban market throughout the summer, and that with excellent profit. Columella describes the gardener returned from the city, his pockets jingling with coin and his head soaked with wine from repeated celebrations of a prosperous day.[26] Certain small plots of land planted with artichokes, in the vicinity of Carthage and of Corduba in Spain, yielded a yearly income of $124.00,[27] thus rivalling the famous artichoke fields in the Carmel River floodplain of California. Megara sc depended upon her export of onions and cucumbers to Athens, fifteen miles away across the Gulf of Salamis, that her market gardeners faced bankruptcy when in 444 B.C. Athens prohibited the trade. Rich Athenian epicures got their earliest vegetables from the nearby islands, where the warm spring stimulated growth.[28]

In addition to these various summer crops, irrigation was required by nearly all agriculture on the southern and eastern margins of the Mediterranean region, where the desiccating trade winds held sway. The Nile valley was a long-drawn fluvial oasis; other wadi oases fringed the African front. The rivers of Damascus and the slender streams of Moab stretched long green fingers into the tawny desert of Syria. Farther east similar conditions of long summer droughts and scant winter rains prevailed in the plain and piedmont of the Tigris-Euphrates valley, where again irrigation became the basis of agriculture. Its principles, there perfected, may have penetrated from the Mesopotamian hinterland westward by way of Syria, Phoenicia, and Palestine; or they may have spread from Egypt around the circle of the Mediterranean coasts. They found vehicles of dissemination at hand in commerce, colonization, conquests and especially the slave trade which distributed skilled cultivators all around the ancient Mediterranean shores from this eastern hinterland.

The Antiquity of Irrigation.—However, irrigation may have been a native discovery made independently in several parts of the Mediterranean Basin in response to climatic conditions. This was possible wherever the uncertain rainfall brought a lean harvest in dry years. While geographic conditions set the problem of supplementing the inadequate precipitation, they also gave the cue to the solution. Everywhere the recurrent floods of swollen winter streams suggested the method of distributing the fructifying waters to the thirsty fields. Nature presented the object lesson, and repeated it year after year with pedagogical fidelity. The theory of independent discovery receives support from the development of irrigation elsewhere in widely separated regions like China, the Melanesian islands, Mexico, and Peru. In all these imitation seems excluded. On the other hand, irrigation stretched across Eurasia in an almost unbroken belt from Spain to India and Java in very early times; here imitation is not excluded.

Legendary history names some of the distributors in the Mediterranean lands. Danae and his fifty daughters, leaving the old matriarchal community of Egypt, established their clan in Grecian Argos and there introduced tillage by irrigation. Phoenicia, which was dominated alternately by Babylonian and Egyptian influences, and early acquired the principles of irrigation, sent out countless colonists whose trail was marked by water conduits and pools, from

Asia Minor to Spain. Cadmus, the Phoenician, in the very act of founding Boeotian Thebes, introduced irrigation; and his descendants doubtless carried this along with the other useful arts which they communicated to Attica.[29] The Greek Heracles, borrowed from the Phoenicians, was the practical benefactor of mankind, teaching the control of water for irrigation. The Etruscans of semi-Asiatic stock apparently taught in Latium principles of irrigation which their colonial ancestors had learned on the Asia Minor coast from Tyrian and Sidonian settlers; and irrigation again followed in Spain and Africa on the arrival there of Phoenician colonists.

Source of the Water.—While the seasonal distribution of the rainfall made irrigation desirable, the prevailing mountain relief of the Mediterranean lands made it possible. High folded ranges rising to 5000 or 7000 feet and peaks towering to 9000 feet or more retained their snow until midsummer. The Sierra Nevada of Spain, Mt. Aetna, Mt. Olympus of Thessaly, the peaks of Lebanon and Mt. Argaeus in the eastern Taurus system showed white patches in shady gorges till late August. The northern ranges, like the Alps, Pyrenees and Rhodope massif, had yet deeper snows owing to heavier precipitation, and kept them longer owing to cooler summers and reduced evaporation.[30] All the highlands were therefore reservoirs of moisture, whose supply in former days was conserved by the forest covering and renewed by the occasional summer showers. These highlands fed their melting snows and their rain into the drainage streams, and thence into the farmer's irrigation ditches, which thus ran full during the growing season of the summer crops, even if they dwindled at harvest time.

Irrigation water was supplied also by the copious springs which issued from the lower slopes of chalk and limestone ridges, especially where the limestone rested on sandstone or crystalline rock. Subterranean reservoirs of the widespread Karst provided a steady flow of water, and therefore were a safer and surer source than the variable mountain stream, which often threatened inundation to the plotted garden or tilled field. The same advantage belonged to the wells sunk to ground-water in valley, lacustrine basin, or coastal plain. These, however, entailed the labor of lifting the water to the surface by well-sweep or wheel pump worked by oxen or asses, as the traveler sees them today in the Tell valleys of the Atlas amid the low-growing vineyards, or in the orchards about Gaza and Ascalon in the Tertiary coastal plain

of Palestine. A rainfall of 16 to 35 inches (400 to 900 mm.) in the Tell valleys and of 8 to 16 inches (200 to 400 mm.) in southern Philistia, reinforced by drainage and infiltration from the nearby slope, supplied enough moisture for winter crops, but during the summer drought irrigation from the numerous wells was imperative then as now.[31] The ancients preferred spring and well water for irrigation because it was cool and fresh, and also because it brought no weed seed to the fields, as did the irrigation ditches fed by drainage streams. On the other hand, wells sunk too near the coast were likely to contain brackish water, which was bad for the purpose.[32]

Necessity for Irrigation.—Fluctuating seasonal rainfall and limited arable area together put the screw upon the ancient Mediterranean farmer, and forced him to his obvious national task of extending his tillage land into desert, swamp and mountain slope. Under state or community direction, he undertook costly reclamation enterprises into which irrigation entered. On the arid margin, east and south of the Mediterranean region, he pushed forward "the line between the desert and the sown," wherever the fructifying waters were available. The soil brought under tillage was rich in phosphorus and potash, which are leached out in rainy lands; the irrigating streams contributed a top dressing of silt to the land and other plant food in the form of mineral salts held in solution. The result was big crops and reliable crops up to the regular limit of the water supply. This was the encouragement to extension of irrigation in ancent Egypt, Syria, Palestine, Carthaginian Africa, and Spain. This explains the flowering orchards and gardens spread out fan-wise in the fluvial oasis of Damascus, which seemed to the weary eyes of Mohammed a Paradise on earth.

I. IRRIGATION OF TERRACED LANDS

Terrace Agriculture.—Irrigation was often associated with the reclamation of mountain slopes by terracing, which contributed to water conservation. The districts commanding a reliable summer water supply were necessarily limited owing to both climate and relief, except in the Nile valley and along the northern rim of the Mediterranean climatic region. They were found elsewhere sparsely scattered over the mountain sides where springs appeared, as on "the slopes of many-fountained Ida," or closely distributed at the base of the ranges, where streams and piedmont springs issued upon the valley floors. Both situations suggested terraces

and contour ditches in order to expand the arable area accessible to the irrigation streams, to conserve the water supply (whether natural or artificial) by checking the run-off, and finally to prevent surface erosion. Hence terrace agriculture was constantly associated with ancient irrigation, especially in those Mediterranean lands which were formerly more populous than now.[33] It meets us in ancient Phoenicia, where the whole country was atilt and where irrigation had been reduced to an art; in Palestine, where "shoulder-stones" of old retaining walls are scattered over the mountains of Carmel, Gilboa and Samaria, once famous for their fertility.[34] Ruins of ancient terraces, designed for barley fields or olive orchards, are found lining the steep valley slopes of Moab and the arid Negeb in southern Judea,[35] where occupancy depended upon the control of springs.[36]

Terrace agriculture early appeared in Greece, probably to utilize the slopes of its fortress heights. This may be the significance of Homer's "terraced Ithome," a mountain stronghold of Thessaly. The steep hill whence Mycenae ruled the Argive plain is scarred by concentric lines of old retaining walls, which suggest to the modern observer terraced vineyards and gardens to supply the table of Agamemnon. Slopes were thus cultivated in Greece more extensively in ancient times than now, for age-long destruction of the forests has impaired the conservation of the water supply and reduced the arable land to 12.5 per cent of the total area.[37] Terracing was doubtless as common in the Aegean Isles as today, when the traveler marvels at the tiers of cultivation rising from the sea shore to mountain crest on Tenos, Cos, Thera and other islands. Their bold relief and small area combine to restrict level land to a minimum. Only Naxos among the Cyclades possesses a lowland. Thera (Santorin), which is the breached rim of an old volcanic crater and measures only three miles in width, culminates in a height of 1860 feet. Melos, another half submerged volcano, has an area of 57 square miles and a summit elevation of 2505 feet. Similar ratios of altitude and area hold in nearly all the Cyclades and Sporades, which are handicapped also by a meager rainfall of 20 inches (500 mm.) or less, (Thera 14 inches, 362 mm.). Terracing alone could extend the crop land and conserve the water supply. Their population, dense in very early times, implied a local food supply; for their mineral wealth was small apart from their marble. Homer speaks of "well-peopled Cos" and "well-peopled Lemnos."[38] Extensive colonization movements from many Aegean Isles as early as the sev

enth century B.C. point to congested population; and the fame of their wines points to terraced vineyards like those covering the slopes of Cos and Thera today.

Roman Italy, with its ampler endowment of plains, might have postponed the hour of terracing; but the fertile soils of volcanic peaks like Aetna and Vesuvius, and the wide distribution of rich volcanic ash and tufa in the Apennines made these mountains early seats of sedentary population, which enjoyed there also better climate and surer water supply than the plains could offer. Hence ancient Italian tillage was associated with terracing and irrigation wherever hill slopes were accessible to distributing canals, or where populous hill towns like those of Etruria, Latium, and Umbria, built in a warring age, exploited all the tillage land within the protecting reach of their citadels.

II. RELATION OF IRRIGATION TO RECLAMATION OF WET LANDS

Irrigation and Reclamation of Valleys.—More important from an economic and social standpoint was the irrigation which attended the reclamation of river flood plains, coastal marsh lands and swampy lake basins; because their abundant humus and composite soils repaid year-round cultivation. Upstream reservoirs and dyked channels made it possible to restrain the swollen winter torrents within their banks, and thus transform flooded wastes into ploughland; but they also provided for the summer irrigation of the low-lying fields. This dual process has been inaugurated from grey antiquity to the present. A recent contract (1928) let to an American construction company by the Grecian government provides for the reclamation and irrigation of the lower Vardar (Axius) valley in Macedonia. Its methods will duplicate in their basic features similar enterprises of nameless ancient engineers, whose accumulated works running through undated centuries were attributed to certain great national heroes.

Irrigation in Egypt

On the Flood Plain.—The network of canals in the Nile floodplain drained or irrigated according to the way the water was controlled. The system of basin irrigation developed by the Pharaohs from the time of Menes (5000 B.C.) was the most efficacious one possible for the Egyptian climate and Nilotic conditions. Only the left bank of the Nile was first reclaimed. A longitudinal dyke was run parallel to the stream on the left bank, and tied by numerous cross dykes to the Libyan hill range on the

west. Into these basins the "red water" of the Nile flood was conducted by natural or artificial channels and allowed to deposit its mud, while it thoroughly saturated the soil. Meantime, the whole right bank and trough of the river furnished passage for the floods to the sea. Reclamation of the right bank did not begin till the Twelfth Dynasty (1380 B.C.); it was a far more difficult project, involving the problem of disposal of excess water by escape-drains through the Delta, so that the water should not be held in the basins longer than forty-five days. Retention of the water for this period secured an adequate top-dressing of red mud and also saturated the subsoil, where this possessed the proper consistency; thus it provided plentiful ground-water which was used in winter and spring for irrigating later crops. It is a significant fact that all the ancient capitals of Egypt occupied sites with extensive subsoil water reserves, which permitted all-year irrigation. Abydos, where the philosopher king Aknaton laid out his pleasure gardens, has the best subsoil water in the Nile valley; Thebes and Memphis have an excellent supply.[39]

In the Delta.—The so-called "plagues of Egypt" were natural incidents of Nile control as practised in the lower Delta or "field of Zoan." In the old days of basin irrigation, and that too from earliest times, according to Sir William Willcocks, it was the Egyptian custom to build temporary earthen dams across the inferior Nile distributaries about twenty miles above their "tails," in order to hold back the flood water and let it overflow the maximum area of land. This was done at the peak of the flood about August first, when the fertilizing "red water" arrived; it was a method invariably adopted in years of "low Nile" to husband the water and extend the irrigated area to the utmost. The exclusion of the fresh water from the tails and the rapid evaporation in August combined to admit the salt water from the Mediterranean, with the result that the river fish died and the frogs beat a hasty retreat to the land. The Israelite settlers living in Goshen near the tails of the east Delta channels saw every year at the time of "red water" myriads of fish floating dead and attributed the phenomenon to "the water turned into blood."

The Pelusiac arm of the Nile, thus dammed below Bubastis during a low Nile to check the out-flow, flooded the Wadi Tumilat, irrigated the grain fields and pastures of Goshen, renewed its sweet subsoil water, and brought plenty to the immigrant Hebrew tribes thereabouts. But it condemned the district of Zoan or

Tanis on the lower Pelusiac Nile to plagues of dead fish, frogs, sand-fleas, flies, polluted wells, with the consequent infection and death of cattle and babies. No miracles these: only the operation of natural laws set in motion by a certain human enterprise under certain geographic conditions. The first and second plagues were ordinary occurrences, produced "also by the Egyptian necromancers," according to biblical statement. The other six came only in a very low Nile, which might occur once in a century or two. "Darkness" was probably due to a protracted northwest wind, bringing clouds of dust to obscure the sun; and the swarms of locusts doubtless came from the deserts of Arabia as they do today. Hail, which is not unknown in the Nile Delta, probably came in late January, since it destroyed the barley crop, then nearly ripe, but did not injure the still immature wheat. The low Nile played no part in these last three plagues, which were fortuitous.[40]

Irrigation in Greece

The embanking of rivers for flood control was a common practice among the Homeric Greeks.[41] They knew "the winter torrent at the full that in swift course scatters the dykes; neither can the long line of mounds hold it in, nor the walls of the fruitful orchards stay its sudden coming, when the rain of heaven driveth it."[42] Yet earlier, in the legendary period, various heroes instituted combined drainage and irrigation works, so far back into the past did these undertakings reach. The characteristic labors of Heracles show him grappling with some problem of water control, whether in Thrace, Argolis, Elis or in Acarnania, where he reclaimed for tillage the flood plain at the mouth of the silt-bearing Achelous. This river, described in legend as a roaring bull when in flood and as a writhing serpent when shrunken to a meandering brook in the summer drought,[43] he embanked and diverted its surplus water by an artificial channel to irrigate the bordering tract of alluvium. The reclaimed tillage land and the crescent course of the new channel which irrigated it, the hero presented to the neighboring King "as the horn of plenty" which all summer produced abundant fruit like apples, grapes, and pomegranates.[44]

Irrigation in Thessalia.—In like manner the Thessalians of Larisa, who occupied the richest portion of the lacustrine basin drained by the Peneus River, embanked this stream to protect their fields from the floods which often washed away the soil into the

overflow basin of Lake Nessonis.[45] But the moderate annual rainfall of this district (20 inches, 502.4 mm.),[46] and the low summer minimum, which makes the Larisian plain in June as dry and dusty as Egypt,[47] offered inducements for irrigation, while the dyked stream, fed by the lingering snows on high Olympus and the Pindos Mts., furnished a ready irrigation system. The abundant and varied food which weighed down the tables of the voracious Thessalians was partly supplied from irrigated gardens and orchards surrounding the capital city. Apparently, too, the low flooded basin of Nessonis, alternately swamp and lake,[48] was frequently reclaimed. Homer fails to mention Lake Nessonis, because, as Strabo surmises, the district was uninhabited owing to inundations; but Simonides of Ceos (556-469 B.C.) speaks of its Pelasgi population.[49] In the fourth century, possibly during the efficient administration of the tyrant Jason (369 B.C.), the swamp of Nessonis was drained so completely, that "after the water was drawn off and the land was dry, the air became colder and frosts more frequent," to the destruction of the fine old olive groves and the occasional injury of the vineyards.[50]

Reclamation produced similar results in the old Lake of Philippi, which occupied a valley basin in the Pangaeus Mts. of southwest Thrace. When the native Thracians occupied the district, so tradition ran, the whole plain was a big forested swamp, a gathering place of the waters from the surrounding mountains,—"*multas aquarum collectiones et stationes habit.*" "But after the basin was drained and for the most part dried out and the whole country brought under cultivation," the district became more subject to frosts.[51] This reclamation was probably instituted by Philip of Macedon after his conquest of the territory in 356 B.C., to furnish local supplies for his new town of Philippi, which was designed as market center for the rich gold mines in Mt. Pangaeus. Hence the enterprise was recent history to Theophrastus writing about it in 313 B.C. It was almost inevitably associated with irrigation, for this coastal belt suffered from scarcity of summer rains and failing streams.[52] Cvijic states that the practice was very ancient and widespread, tracing back to an oriental or Byzantine origin; that irrigation canals, constructed on the ancient plan, were mentioned in the charters of the Serbian kings of the thirteenth centry. They are numerous today in the basin of the Meglen River, which formed the heart of Philip's Macedonia, and which now regularly yields two crops annually under irrigation.[53]

Irrigation in Southern Greece.—Farther south, in the narrow peninsular area of Hellas and Peloponnesos, where the valley plains contract, the arable land shrinks, rainfall declines, and summer drought lengthens, reclamation and irrigation became increasingly urgent. The Eurotas River of Laconia was ascribed to a large canal constructed by Eurotas, a mythical king of Sparta, to drain the Spartan plain.[54] The legend probably epitomized centuries of piece-meal reclamation; for this middle section of the Eurotas valley, blocked on the south by the Bardunochoria hill belt which cuts it off from the sea, was formerly a Pliocene inland lake, which was slowly drained as the Eurotas eroded its gorge through the limestone barrier to the Mediterranean.[55] The process was incomplete even in historical times. The ancient city park Plantanistas or Planetree Grove occupied an artificial island surrounded by channels of the braided stream[56]—evidence of water control,—while Limnae, an urban district of Sparta in a depression by the Eurotas, had its name from the former marshes there. Its temple of Dionysos occupied a wet site, which in the course of time was drained.[57]

In the Karst Country.—The karst country of Greece utilized for irrigation its great "fountain-heads" or kephalari, surface vents of underground rivers; these were often so copious and had so many "heads" or mouths that they formed considerable streams and necessitated reclamation enterprises to control and distribute the water. The River Erasinos, which issues near Argos from its twenty-mile subterranean course from Lake Stymphalus, has force today to drive a dozen mills, and in ancient times served to water the adjacent Argive plain.[58] In a cavern above the spring sacrifices were offered to Dionysos and Pan, both gods of husbandry; and now in mid-August a Panegyris is annually celebrated here, for the summer drought is just as severe and the human need is just as great. Six miles south of Argos, on a narrow coastal strip at the base of Mt. Pontinos is the gushing spring of Amymone, which forms the Lerna River and swamp. Here Heracles, "man's great benefactor," fought the monster Hydra or water snake with its nine heads; and as soon as he severed one head two others sprang out in its place.[59] The spring gave evidence of strong hydraulic pressure. In ancient times it watered a sacred grove of plane-trees, where solemn rites were celebrated in honor of Demeter and Dionysos, gods of tillage.

In Boeotia.—Boeotia was the scene of various reclamation projects from the legendary period to recent times. Cadmus of Tyre, a typical Phoenician engineer and colonist, "was directed by the gods to fix his abode in the rich wheat lands where gushing Dirce's fair streams pour their water over green and fruitful fields." But a dragon had its lair in a limestone cave beneath the high Cadmean citadel; it ravaged the Theban plain and "watched with roving eye the watered vales and quickening rivulets."[60] This monster typified the mighty spring of Ares, which the hero snared in a network of canals and thus held captive. He converted its devastating streams into beneficent water conduits, and made the Theban district the most productive in Greece. An unknown writer about 250 B.C. thus describes the area: "All its parts are level, its form is circular, and its hue black like the earth. Everywhere well-watered, verdant, undulating, it includes more gardens than any other city in Greece. For two rivers flow through its precincts, watering all the level land adjoining their banks, and hidden springs descend from the Cadmeia in artificial channels, said to have been constructed by Cadmus in very ancient times."[61] Today several large tanks of ancient masonry with inscribed tablets impound the water of the famous Dircean springs and distribute it to the surrounding gardens. They stand there, still performing their age-long service, mute intimations of the immortality of geographic forces in history.

Boeotia contained also several enclosed lake basins with underground outlets typical of the karst regions of Greece. They furnished admirable soil but were subject to inundation when the natural vents in the underlying limestone became choked up or proved inadequate to carry off the winter floods.[62] Lake Copais, the largest of these basins, shrank to a reedy swamp in late summer, but when it attained its highest level in late winter, covered an area of ninety square miles.[63] Theophrastus, on the basis of old traditions, estimated that this occurred about once every nine years; though its duration was variable. At the time of the battle of Chaeronea (338 B.C.) and for several years before, Lake Copais was deep; it filled up again later at the time of a severe plague, but failed again in winter.[64] During sustained droughts, the lake dried up so completely that all the aquatic vegetation became sere.[65]

The earliest inhabitants of this lacustrine plain, dating back to Minyan Orchomenos (2000 B.C.) or yet earlier to the Stone Age, kept Lake Copais at a low level and thus reclaimed for tillage a wide zone of fertile land by constructing canals and enlarging the

openings or katavothra to the underground channels.[66] These ran eastward under Mount Ptoon and debouched as great springs near Larymna on the Euboean Sound.[67] The traveler in Boeotia today sees the masonry of the ancient dykes, and caverns in the mountain shore which mark the tunnel course of the katavothra. Drainage works, executed by a British company about 1890, consist of a girdle canal which intercepts the affluent streams on two sides of the Copais basin, and discharges its water by a series of tunnels and minor katavothra lakes into the Euboean Sound.[68] Significantly enough, it is a belated copy of a girdle canal described by Plato as encircling the mountain-rimmed plain of the mythical Atlantis and connected with a network of conduits intersecting the plain.[69] Plato doubtless copied the reclamation system in operation in several lake basins of Greece.

Reclamation of Lake Basins, Boeotia.—These reclamation works about Lake Copais recovered many thousand acres of irrigable tillage land and founded the agricultural wealth of Gla, Orchomenos, Copae, Acraephium, Coreneia, Haliartos, and other places. All these cities occupied hill or mountain sites for safety from the recurrent inundations. Even so, the rising waters often trapped them. The legendary history of Boeotia abounds in tales of towns swallowed up by floods; it had its local variants of the deluge myth with quite distinctive features. The underground outlets of Lake Copais became obstructed with serious results in the time of Alexander the Great, when Crates of Chalcis, a mining engineer, undertook the work of clearing out the channels; but he left his task unfinished when an insurrection broke out in Boeotia. This was the period of high water alluded to by Theophrastus.

A different method of combined drainage and irrigation was devised by the inhabitants of ancient Thisbe, who occupied a small katavothra lake basin on the southern slope of Mount Helicon in western Boeotia.[70] They ran a dyke through the lake along the axis of its drainage; every second year they diverted the water to one side of the dyke, and tilled the land on the other, which was soaked with moisture and naturally fertilized by decayed vegetation.[71]

Of Lake Basins in Arcadia.—The rugged highlands of Arcadia abound in similar lake basins, which in ancient times furnished the best arable land but were subject to inundation. Efforts of ancient engineers to control the fluctuating water level and reclaim

the land for tillage were epitomized in the symbolic labors of Heracles. The hero, for instance, rescued the plain of Lake Stymphalos from a plague of foul birds, symbolizing the torrents which rushed down from the surrounding mountains and devastated the land.[72] Lake Pheneos, whose surface has for ages oscillated with the seasonal rains and the open or obstructed conditions of the underground discharges, was in antiquity a fertile plain.[73] The stream feeding the lake was conducted across the plain to a katavothra by an embanked canal, five furlongs long and thirty feet deep, ascribed to Heracles. When everything was in order above and below ground, it reclaimed nine square miles of fertile land, and made Pheneos a prosperous cantonal state in this ancient Switzerland of Greece. But the district was never safe from floods. Lying 2470 feet above sea level, surrounded by mountains from 2000 to 4400 feet higher, and subject to sudden storms, the little state found it wise to locate its capital city six miles from the katavothra and well up on the rim of the basin; but even so it once suffered from inundation.[74]

Farther south, a series of four small katavothra basins, occupying the graben of eastern Arcadia and lying about 2000 feet above the sea, were reclaimed for the sake of the rich brown loam which covered their floors. Gradual deposition of silt from the surrounding slopes tended to raise the level, clog the drainage canals and choke the underground outlets; but the work of reclamation went on. The lake plain which fed the lofty city of Orchomenos (3070 feet) in the days of its greatness had an area of only four square miles. In the time of Pausanias it had reverted to a mere. The adjacent plain of Caphyae had its stream canalled and conducted to a katavothra.[75] The larger basin of Mantinea was carefully drained by canals and katavothrae,[76] and formerly supported a considerable population on its fluctuating eight square miles of fertile land. But a hill range on the south separated the Mantinean district from the larger basin of Tegea, which lay 100 feet higher and after heavy winter rains overflowed through a narrow defile into the Mantinean mere.[77] The regulation of the water in this course occasioned continual strife between the two towns. Prior to the seventh century B.C. and even in the pre-Dorian age, Tegea was a powerful state. It evidently inaugurated reclamation works at a very early date, to exploit the fertile lacustrine soil which formed the heart of its territory.[78] The main katavothra, a low cave in the rock wall at the southwest corner of the marshy lake, can still be seen from the highroad

crossing the mountains to Sparta; and still it serves to drain the vineyards and wheatfields which support the modern town of Tripolis, successor of hoary Tegea as metropolis of the basin.

Reclamation Enterprises in Italy

Reclamation Methods in the Etruscan Era.—Reclamation enterprises in Italy go back into grey antiquity and generally appear under Etruscan initiative. Several lakes or swamps (*paludes*) in and about Rome figured in the early chronicles but disappeared later. Such were the Goat's Marsh, where Romulus was struck by lightning, the Curtian Lake mentioned as existing in 745 B.C., Lake Regillus near Tusculum where the Romans defeated the Latins in 496 B.C.[79] The marshy valley between the Palatine and Capitoline Hills of Rome was doubtless reclaimed and cultivated at an early period. The Cloaca Maxima, ascribed by tradition to the Tarquin kings, originally served this purpose and may be classed with drains found in other Etruscan towns like Graviscae, port of Tarquinii, located on a marshy coast. Clusium, overlooking the swampy lake-strewn valley of the Clanis River, rests upon a labyrinth of underground passages which probably belonged to an elaborate drainage system similar to that at Praeneste.[80] The district below Velitrae, which lies in the southern slope of the Alban Mts., is honeycombed with a system of tunnels or *cuniculi* running down towards the Pontine marshes. They probably served, as has been suggested, to carry off excess water from the swollen torrents and reduce erosion in the bordering fields. Ancient dams of polygonal masonry are found in the Scarabellata gorge, which scars the steep seaward slope of Monte Gennaro (4160 feet), the highest peak of the Sabine Mountains;[81] and they seem designed to check the run-off and conserve the water for irrigation. In all these districts, Etruscan influence once prevailed.

Another Etruscan method of reclaiming land consisted in drawing off water from volcanic lakes by cutting tunnels through the crater walls. All the crater lakes in the Alban Mountains were tapped in this way. The tunnel emissarium of Lake Albanus was 1300 yards long. It was constructed, according to tradition, in 397 B.C. during the siege of Veii, when the lake filled up and threatened to overflow; but it was possibly much older. Livy's garbled account ascribed the plan to Etruscan soothsayers, who urged the Romans to use the water for irrigation and "scatter it harmless over the fields."[82] A longer emissarium tapped Lake

Nemi at some unknown date, reclaimed for gardens and vineyards the shallow north end of the basin, and opened below through the old crater wall of Lake Aricia, which lay eighty-five feet lower. Thence its water was conducted in a canal which drained the shallow basin of Aricia, and issued by a tunnel through the low crater rampart on the southwest into a river. The old town of Aricia, whose citadel lay on a hill, belonged to the early Latin League; and its fertile basin, where irrigation is still maintained, became famous for its leeks and cabbages.[83] This lake region was the heart of the old Latin territory. Pressure of population doubtless forced it to these reclamation projects under Etruscan direction. The amount of arable land recovered was small, but its quality was excellent and facilities for irrigation lay to hand.

The tunnel and *cuniculi* drainage of Latium and southern Etruria, like the dyking of the lower Arno by Etruscans or Greek Pisans, belongs to prehistoric times; but similar reclamation enterprises were carried on with no appreciable break by the Latins and later Romans. The old lacustrine basin of the Velinus River in the Sabine country was subject to progressive inundation caused by deposits of travertine which dammed the outflow. It invited reclamation because its meadows and wet pastures were famous for their fertility and were located only about fifty miles from Rome. Hence a succession of drainage canals were made, the first in 271 B.C. by Manius Curius Dentatus; but the rising of the river bed necessitated fresh cuttings in the old channels or the construction of new ones.[84] Efforts to drain Lake Fucinus, which occupies a shallow, mountain-locked basin in the central Apennines, were stimulated by the rich soil around its shelving shores. The width of this arable zone varied widely with the rising and falling of the water level, which were very irregular; for the lake was "vast as a sea and of great service to the Marsi and all the surrounding nations."[85] The drainage enterprise was a big one, therefore. It was attempted with partial success by the Emperor Claudius in 52 A.D.; renewed by Hadrian, but accomplished only in 1875 by Prince Torlonia, who constructed a double tunnel emissarium four miles through a range of the Apennines to the Liris.

Reclamation of the Pontine Marshes.—Attempts to reclaim the Pontine marshes of Latium and the Maremna of Etruria were also big undertakings and urgent ones, because they lay in the heart of the old Roman territory and fringed a much used coast. The Etruscan towns like Volci, Vetulonia, Rusellae, Cossa, Tar-

quinii, and Caere were situated on spurs of the upland a few miles from the sea, and only their ports lay on the marshy shore. Populonia which occupied a lofty promontory (938 feet), an old "tied" island, with a little harbor at its base, was the only ancient Etruscan town located on the sea.[86] The Pontine marshes, which were reputed to have been once dotted with flourishing villages,[87] reverted to a permanent swamp during the Republic, probably due to slow subsidence of the basin or buckling of the coast. Efforts to drain the marshes were made by Appius Claudius in 312 B.C. according to tradition, by Cornelius Cethegus in 182 B.C., by Julius Caesar, Augustus, Nerva, Trajan, and finally by Theodoric the Goth. All achieved only temporary results, because the problem was apparently a progressive one, which is still engaging the attention of the Italian government.[88] In the time of Strabo, the great drainage canal along the Via Appia from Terracina was used for canal boat transportation between Rome and the coast.[89] Reclamation was evidently stimulated after the Hannibalic War (204 B.C) which was probably responsible for the introduction of malaria into Italy from Africa.

In the Po Valley.—The canalization of the Po, which was subject to heavy spring floods, was begun by the Etruscans who diverted the sluggish waters of the river into the coastal swamps, in order to facilitate communication between the seaport Adria and the Adriatic.[90] Aemilius Scaurus in 109 B.C. drained the plains south of the Po between Placentia and Parma by means of navigable canals, in connection with the construction of the Aemilian Way.[91] This road traced the north base of the Apennines and ran through a succession of new colonies whose fertile territory, developed by drainage and irrigation, could profit by land and water communication, and stabilize Roman power in this frontier province.

These government enterprises accomplished on a big scale what the Etruscan and Roman peasants had been doing on their farms every year on a small scale. With the advent of the autumn rains Cato directs all farm hands to work with pick and shovel, clearing out the drainage ditches or making new ones to carry off the excess water.[92] Vergil, recalling his boyhood impressions of his father's farm by the Mincio River in the Po lowland, describes the whole country-side as "afloat with brimming ditches during the winter rains." In such districts a gridiron of trenches was necessary. From the furrows of the ploughland, the water ran into transverse channels and thence into open ditches.[93] A heavy

rain involved emergency work to prevent the canals from getting choked with mud and debris. Hence this was a permissible task for feast days, when other agricultural labor was forbidden.[94]

Riparian Laws in the Roman Empire.—The Roman law reflected the necessity of water control. It required neighbors to maintain the dykes and clean the trenches forming part of a common drainage system, in order to expedite run-off and prevent overflows.[95] Down-hill estates were made subject to higher lands for drainage, a servitude imposed by nature but compensated in part by the rich soil washed down from the upper fields. However, law (*actio aquae pluviae arcendae*) provided redress if a farmer dammed a swamp or lake to exclude the flood waters from his own land, and thereby forced them to seek new outlets to the detriment of a neighbor's land below; or if he diverted the rain water from its natural drainage course on his own farm, and overloaded the channel running down into his neighbor's farm.[96] But the owner of the upper estate was free to impound water flowing on to his own land, for purposes of irrigation or other use, and could thereby intercept it from the farm below.[97] The law authorized any man to embank a river flowing through his land, and also to construct dykes and ditches on a neighbor's estate, where these were essential to his plan for flood control.[98] Moreover such works were protected by law. If unjustly destroyed, they had to be restored by the offender; but if swept away by the violence of the river in spate, there was no redress.[99]

III. IRRIGATION IN DRY LAND REGIONS

Aside from irrigation associated with reclamation enterprises, the Mediterranean region presented many phases of irrigation by which the ancient farmer merely endeavored to get available water onto the land. His object was to vary and amplify the yield of his farm by raising summer crops; or, in case of need, to supplement the scant winter rains of dry years or of dry localities, where recurrent droughts brought recurrent failure to the winter crops and jeopardized the fodder supply of the farm animals. The marked variability in the amount and duration of the winter rains in the Mediterranean climatic region, the growing density of population, the increasing wealth and culture in the big urban centers which made a demand for increasing table luxuries, all combined to stimulate irrigation. Hence this particular form of intensive agriculture became widely distributed in the Mediterranean lands

and some of its finest phases, like elaborate floriculture, trace back to extremely early times. A detailed survey of its distribution will make this clear.

Irrigation in the Dry Season in Egypt.—The control of the Nile floods was a preliminary to the regulation and distribution of its waters; for the problems attending these national tasks underlay all Egyptian government and science, animated much of its religion. The peasant turned from the harvests of his flooded fields in March to the irrigation of his spring fields by well and shaduf.

Irrigation in Northern Africa

In Cyrenaica and Westward.—Farther west, where the level expanse of the African coast domes up in Barca Plateau, this highland attains sufficient altitude (3300 ft. or 1000 mm. in the west) to collect an annual rainfall of 11 inches (276 mm.) with wide fluctuation between 5.5 and 24 inches,[100]—enough for grain in average years by the help of the dews and dry-farming methods, as is the case today.[101] The products were typical of a fertile soil in a semi-arid karst region. But one notes the presence of terrace springs and short streams wherever gardens, orchards, and vineyards flourished, as about Cyrene, Hesperides, Barca, and Darnae.[102] Diodorus Siculus lauds the fertile soil, the vines, olive groves, trees, and herbs about Cyrene, and then adds, "It excels also in the convenience of its streams. The land to the south where the nitre comes out permits no tillage, being bereft of flowing water, and it presents the appearance of the sea."[103] The coast town of Darnae owed its existence to a little stream, fed by two full springs, which today serves to irrigate gardens in the delta. Ruins of aqueducts and reservoirs show that the Romans conserved the water resources of Cyrenaica to the utmost, despite the difficulty of making storage tanks in the porous limestone.[104] The prosperity of ancient Cyrene was based on silphium, a wild native plant of the steppes; and when that was exhausted, the state declined.

Yet farther west, where a high escarpment of the African plateau approaches close to the Mediterranean and suffices to condense the winter rains (16 inches or 391 mm.) a few wadis find their way to the shelving coast and maintain high ground water in the littoral. Here in the Cinyps valley, where "the soil is black and well watered with springs," grain fields flourished under the combined effect of rains and dew; and irrigation helped in years

when the precipitation declined to nine inches or less.[105] At the head of the Syrtis Minor, in the rain-shadow of the Atlas Mts. precipitation became negligible and tillage frankly depended on irrigation. There lay the port of Tacape (rainfall 7 in., 183 mm.) occupying a small district of only nine square miles but great fertility, located in the midst of the sands. Through it flowed an unfailing spring, abundant to be sure, but only at certain hours were its waters distributed among the inhabitants; for its irrigation ditches fructified orchards of olive, figs, and pomegranates, with fields of wheat, pulses, and garden herbs growing beneath their grateful shade among the murmuring rivulets. No wonder the ground was costly.[106]

In Atlas Mountain Region.—Only the high mass of the Atlas system, accessible to the rain-bearing winds from the west, ensured abundant water for irrigation. The Tell valleys, near the coast, get enough rain for winter tillage; but all the inland valleys were in ancient times, as today, dependent upon irrigation. When Agathocles of Sicily invaded Carthage in 310 B.C., he found the land beautified with gardens and fruit trees; sluices and canals were cut all along to convey the water by which the whole tract was abundantly irrigated. There were orchards of pomegranates, figs olives, pears, and cherries, besides extensive vineyards, nearly all of which presupposed irrigation in this tradewind district. The fact that Carthage was importing grain in the third century B.C., according to Diodorus Siculus, points to the larger profit of horticulture by irrigation.

Eight centuries later Procopius gave a similar description of Vandal Africa. Landing at Caputvada or Shoal Head with the army of Belisarius in 535 A.D., he marched northward along the coast of Byzacium for 120 miles to Carthage. It was summer, but the orchards were full of fresh fruits. The soldiers, digging the trench about their camp on Shoal Head, struck a gushing stream of water a few feet below the surface in the midst of an arid steppe, evidence of high ground water; and the next morning they raided the fruit orchards of the nearby farms. Thence all the way north the country people sold abundant supplies to the army, which often pitched its tents amid trees laden with fruit, beside spring-fed rivulets.[107] Irrigation and high ground water explain the summer productivity of this coast land of Byzacium, where winter wheat throve from early times with a mean annual rainfall of scant sixteen inches (Hadrametum or Sousse, 406 mm.).

Near Utica and Carthage.—Farther north about Utica and Carthage, where the Atlas ranges approached the sea, the summer crops had abundant flowing water. The busy port of Hippo Diarrhytus (Bizerta, rainfall 642 mm.) got its name from the canals irrigating its little plain. It is no wonder that Carthaginian fruits and vegetables, such as asparagus and artichokes, Numidian pears, and cherries, enjoyed a great reputation. But sixty miles west of Carthage, in the valley of the Bagradas River, was Vaga, the busiest market of northern Numidia, located in the rain shadow of the northern Atlas. Therefore when the Roman army camped there in the summer of 109 B.C., they found the country about it "a desert owing to the dearth of water, except the places along the river; these were planted in orchards and were resorted to by flocks and the cultivators,"[109] who clearly brought their stock to the irrigated meadows in the summer drought.

In the Interior.—Nor was intensive tillage by irrigation restricted to the Romanized population of the coastland. The native Massylii of inland Numidia diverted the River Abigas (Wadi Bu Duda) which flowed down from the high Aures Mts. (7585 feet, 2310 m.) past the town of Bagais (Baghai), into the Shottel Tarf, and distributed it by canals over the arid piedmont plain. They stopped the channels with earth to check the flow and opened them at will. Similar plains in this highland region, where streams and springs sufficed, were made to produce excellent grain and fruits.[110] The districts of Tamugadi (Timgad), Lambaesis, and Lamasba, located at the northern base of the Aures Mts. at an altitude of about 3350 feet (1050 m., rainfall 12.5 to 15.5 inches) had extensive storage works for water, on which tillage depended.[111] The ruins of Lamasba, which lay near the modern site of Batna on the Trans-Atlas railroad, comprise an ancient inscription, dating from 220 A.D. It records the water rights of forty-three or more farms in the commune, and specifies the hours and exact dates when each estate might receive water. Plots were classified as *declives* or below the reservoir level, and *acclives,* or above, to which water had to be pumped. The "descendent" water was left flowing for fewer hours than "ascendent" water, because the latter was more slowly delivered. The amount of water was determined also by the size of the estate or the size of its harvests, it is not clear which. A small farm received "descendent" water for an hour in late September, and one four times as large received it for four and a half hours. Of

two farms, about equal in size or products, one received ascending water for sixteen and a half hours, and the other received descending water for ten and a half hours. These regulations, which aimed to secure impartial distribution in a region of inadequate rainfall and intense evaporation, were issued by the local senate and people.[112]

Irrigation in Syria and Palestine

In the lands bordering the eastern end of the Mediterranean, similar conditions of long summer droughts and uncertain rainfall obtained, with the consequent need of artificial watering. The early Aramaic-Semitic peoples of Syria and Palestine brought this secret of desert tillage from the stream oases of highland Arabia, and the invading Israelites adopted it along with other practices of sedentary life.

In Palestine.—In Palestine irrigation relied upon springs, underground water, cisterns, and a few perennial rivulets—"a fountain of gardens, a well of living waters, and streams from Lebanon."[113] It was constantly associated with horticulture in the Bible, where the well-watered garden was the symbol of generous blessing. But irrigation was applied also to field and meadow,[114] to vineyards, orchards, and groves. "I made me gardens and orchards, and I planted in them all kinds of fruit; I made me pools of water to water therewith the wood that bringeth forth trees."[115]

The narrow margin between food and famine, resulting from variable rainfall and porous limestone soil, made irrigation in Palestine a desirable resource. In those year-long periods of drought from which the country frequently suffered, every drop of water was conserved. Hence the surface of the country is pitted with ancient cisterns and reservoirs, whose restoration would renew the productivity of the land. The three great "Pools of Solomon" near Jerusalem are artificial tanks, measuring from 127 to 194 yards in length, from 49 to 76 yards in width, and from 25 to 48 feet in depth, fed by conduits from neighboring springs.[116] The average rainfall in Jerusalem, at an altitude of 2600 feet, is 26 inches (649 mm.); but it drops to 20 inches (520 mm.) at Joppa on the coast and to 16 inches (420 mm.) at Gaza farther south. Both districts require irrigation for complete exploitation in good seasons, and for a partial crop in years of diminished rainfall. Abundant springs issue from the western base of the Judean Plateau, fed by the seepage waters of the long western

slope. They are in reality the surface mouths of underground streams, and are therefore copious enough to supply distributing canals. Others like them water the base of Mount Carmel and Gilboa.[117] All these doubtless served to irrigate the scattered gardens of Palestine during the long summer drought. At the seaward edge of the Maritime Plain, wells sunk to the underground waters which everywhere underlay the fertile soil, kept alive the flourishing gardens and orchards of Ashdod, Askalon, and Gaza.

In the wilderness or desert of Judea, that arid eastern slope which sinks abruptly to the Dead Sea, no cultivation was possible, except where an occasional spring, like that of Engedi, bursting forth from the porous limestone escarpment, created an oasis as far as its waters reached. In the time of King Saul, as in that of Josephus (75 A.D.), the oasis of Engedi spread in a succession of vineyards and gardens,[118] fed by brimming canals, 600 feet down to the Dead Sea. A nearly rainless climate, due to descending winds and intense heat, prevailed along the whole eastern base of the Judean Plateau, where this joined the sunken Jordan plain. Fertile soil on the natural terraces of an old lake basin offered attractive conditions for tillage, while fountains and spring-fed wadis afforded water for irrigation. Hence these old Jordan lake strands became from remote times the sites of flourishing agricultural towns, like Jericho, Pharselis, and Bethshan.

The situation of Jericho was typical. Located on a broad lake terrace 470 feet above the Dead Sea and about eight miles from the Jordan, it enjoyed excellent irrigation and drainage for the palm and balsam groves which made it famous in antiquity.[119] These plantations, extending northward for a hundred stadia or twelve miles and merging into those of Phaselis at the mouth of the Wadi Ifjion, included also various other cultivated trees which produced excellent fruits.[120] A reputation for fertility, "the fattest of Judea," belonged to Jericho equally in the time of Joshua and of the Latin kings of Jerusalem.[121] The modern traveller visiting the site today sees above the town the ancient tanks, one of them six acres in extent, whose conduits once made this district a miniature paradise.

Yet farther north, in the canyon mouth of the Vale of Jezreel, lay the fortress city of Bethshan, surrounded by gardens and orchards on the last broad terrace of the Jordan. Its irrigation streams were so abundant that during a Saracen attack in 634 A.D., they were poured out to convert the surrounding flats into

a marsh and thus held the enemy at bay.[122] When it is remembered that this western terrace of the Jordan lay from 430 to 830 feet below sea level in the superheated rift, and from 2000 to 3400 feet below the summit of the plateau, whence the drying winds descended, and that this district was famous in antiquity for its grain, dates, flax, balsam, and other products, as for its sugar-cane under thrifty Saracen tillage, the conclusion is unavoidable that this was a banner district for irrigation, a conclusion that is corroborated by the scattered ruins of tanks and aqueducts.

In Phoenicia.—Phoenicia, owing to its more northern location and its bold mountain relief facing the rain-bearing winds from the west, had ample precipitation for winter tillage. But the steep slopes exposed the fields to over-rapid drainage and surface erosion, that would scour off the forest-made humus. Hence, physical conditions necessitated terracing at an early date, while the populous cities which exploited the patches of coastal plain made insistant demand for the additional food supply yielded by summer tillage. Consequently, both agriculture and irrigation were highly developed here in remote antiquity. Olive groves, orchards, vineyards and gardens, all requiring intensive cultivation, covered the littoral and dotted the slopes to an altitude of two thousand feet or more;[123] for at this elevation remains of ancient temples and other buildings have been found. Even today, the traveller coming from Damascus to the coast issues from the high tunnels of the Lebanon Mountains, as if he had thrust his head out of a window, and sees below him vineyards mantling the slopes up to a height of 2500 feet, and terraces of irrigated cultivation climbing far up the wadi walls. The Phoenicians were masters in the art of embanking and irrigating and were regarded as such by the Greeks,[124] whose engineer heroes, like Cadmus and Heracles, came from Syria.

In Coele-Syria.—Behind the wind-shield of the Lebanon Mountains, the need for irrigation increases with every added mile away from the coast and with every drop in altitude. The long line of cities and towns which from most ancient times traced the great north road through the Lebanon Trough from the sources of the Jordan to Antioch and Aleppo owed their agricultural wealth to the rich soil and abundant flowing water.[125] The great productivity of Coele-Syria under imperial Rome was due to effective equipment and adminitsration of the water supply, which was furnished by the Orontes River, its western tributaries, and the full springs on the

Lebanon flank. Damascus, located about seventy miles from the Mediterranean on the edge of the Syrian Desert, behind the double screen of the Lebanon and Anti-Lebanon, in the rain-shadow of their towering ranges, has relied through the ages upon their snow-fed brooks to water her wide expanse of gardens, fields, and orchards. The rushing Barada issues from its canyon and flings abroad tassels of silver streams across the outstretched plain; the Pharphar brings its tribute from the copious springs of Mt. Hermon (9050 feet.) Only this delta of fertility, murmurous with the running water of countless canals, creates the Garden of Damascus between the Syrian Desert in front and the sterile plateau of Es-Sahara behind. In spring a cloud of pink and white blossoms broods over the oasis when the almond and plum trees are in bloom; in summer a vast stretch of green foliage shades off into the grey rolling steppe and the gleaming salt lake on the desert rim.

Irrigation of the Dry Lands of Greece

In Ancient Greece.—The ancient Greeks practiced irrigation from remote times, certainly before the tenth century B.C. The fine passage in the Iliad, which describes the peasant turning the stream into the ditch to water his fields and garden,[127] is echoed in the Odyssey, where a spring-fed canal waters the garden of Alcinous, and the waste from a roadside fountain waters a group thirsty plane-trees.[128] Sophocles, who belongs to the golden age of Athens, describes the flowery fields of the Cephisos valley kept green by irrigation.[129]

"And there, beneath the gentle dew of heaven,
The fair narcissus with its clustered bells
Blows every day by day,
Of old the wreath of mightiest goddesses,
And crocus golden-eyed;
And still unslumbering flow
Cephisos' wandering streams."

Today the parcelled waters of the Cephisos are still distributed to the fields and gardens of the peasants by small canals which are called, in modern Greek, by almost the identical word used by Sophocles.

The chief centers of population in ancient Greece were located on the eastern side of the peninsula within the Aegean sphere of influence, and therefore lay in the rain-shadow of the western

mountains. Hence low and uncertain rainfall (16 to 20 inches) and long summer drought made irrigation imperative for their summer tillage. Cadmus and Danaus, immigrants from the East, were the mythical founders of artificial irrigation. Danaus, the hero-king of "thirsty Argos," whose imputed works probably represented the collective achievements of generations of the agricultural Danae tribe, introduced tillage and opened springs and wells, whereby he converted a barren waste into a fertile and well-watered plain.[130]

Knowledge of in Plato's Time.—In Plato's model republic, the citizens constructed aqueducts across valleys in order to irrigate outlying gardens;[131] they conserved the water supply and prevented floods by damming mountain torrents, that the water thus impounded "might produce streams and fountains for the fields below them and for all places, and thus cause the dryest spots to possess water plentiful and good."[132] So familiar were the ancients with the principle of impounding water that certain early writers mistook Lake Gygæa or Coloe, located four miles from Sardis in the Pactolus valley, for an artificial reservoir.[133]

The long-established organization of irrigation is reflected in the system of water-rights which Plato formulated for his ideal Republic, doubtless in imitation of the Attic laws.[134] These were explicit and elaborate, as one would expect in a state which had no perennial streams and which had to depend upon springs or wells sunk to ground water, or upon artificial ponds or tanks. The office of water commissioner in Athens was once held by no less a man than Themistocles, who made a bronze figurine called the Water-carrier from the fines imposed on those who had taken water illegally.[136]

Irrigation of Dry Lands in Italy

Italy, though located farther north and west than Greece, and therefore blessed with more abundant precipitation, yet suffered enough from summer drought to make irrigation necessary for the Roman farmer, as it is for the modern Italian peasant. Ancient Latin writers on agriculture recommended irrigation for various crops. Horace praised "the orchards watered by the flowing rills," but his fastidious palate condemned excessive irrigation and found "nothing poorer than a washed-out garden" with its insipid vegetables.[137] But "the endive rejoices in the rivulet that it sips," says Virgil.[138] Cicero enumerates aqueducts, the damming of

streams, the tapping of rivers, and the irrigation of the soil as among the great works of man.[139] Frontinus, water commissioner for the city of Rome in 97 A.D., reveals in his famous Report an old illicit trade in drawing off water from the public aqueducts for irrigation, between the city and the distant intakes in the mountains. But aqueduct water from impure or muddy sources, like the River Anio, was regularly reserved for the irrigation of gardens in and about Rome.[140]

In the Alpine Piedmont.—Even in the Alpine piedmont of northern Italy where summer showers occur, irrigation was practiced in ancient times. In the second century B.C. the people of the lower Doria Baltea valley utilized that river to irrigate their fields; but the Alpine tribe of the Salassi, who lived up-stream and worked extensive gold mines, drew off practically all the water of the river to wash the gold. The situation occasioned numerous conflicts between the up-stream and down-stream peoples, until the Romans conquered the country in 143 B.C.[141] Vergil, who doubtless in his boyhood often saw the waters of the Mincio River diverted to his father's farm near Mantua, beautifully describes the summer irrigation of tillage lands. The good farmer "guides over the crops the chasing runlets from the river; and when the blade is dying in the scorched and feverish field, look! on the brow of the slope he lures the water from her channels, and the rushing stream wakens a hoarse clatter among the smooth pebbles, and gushes cooling o'er the parched fields."[142]

Reclamation of Dry Lands in Iberia

Of the Coastal Lands.—Irrigation in Spain is rarely mentioned by the ancient authorities, but it may be inferred from the evidences of advanced agriculture under the climatic conditions of the Iberian Peninsula. The productiveness of tillage in Lusitania (Portugal), indicated by the low price of food in the second century B.C.,[143] doubtless resulted from the alluvial soil and ample rainfall (25 to 40 inches) of the western littoral. The Mediterranean coastal strip, characterized by low rainfall (14 to 20 inches) and very dry summers,[144] was the most populous and productive section in Carthaginian and Roman times. Olives, figs, vines, and all kinds of fruit trees abounded where today flourish the famous *huertas* or irrigated gardens of Spain,[145] using water channels dating back to Roman times. Murcia was arid in ancient times as it is today. Its parched coastal plain near New Carthage was irri-

gated from the Tader River (Segura) to raise the spartum reed, which supplied the ancient port with cordage and later supported a big local industry.[146] Wheat fields and vineyards today in Murcia often need irrigation, just as they did in ancient times, according to Justinus.[147] In Spain it was not uncommon for the vintager to gather grapes in flooded vineyards, Pliny tells us.[148]

This expert irrigation agriculture in Spain was confined to the coasts which had long been under the stimulating influences of Phoenician and Greek colonies; it presented a marked contrast to the backward tillage in the interior of the peninsula, where the absence of olive and vine only a few miles back from the sea, and the use of butter instead of oil, point to isolation from stimulating contacts.[149] Where such contacts had been old and active, progress was great.

Engineering Skill in Southern Spain.—Roman authorities agree as to the careful tillage, skillful mining, and advanced civilization of the native Tartessians or Turdetani of the Guadalquivir valley and the southern littoral. The language and burial customs of these ancient Spaniards point to immigration of far-ranging Mycenaean Greeks,[150] while the century-long presence of Phoenicians in their midst would amply explain their progress in mining and tillage. The master miners of the Lebanon Mountains, eager to trade in the copper, gold and silver of Spain, probably instructed the ancient Tartessian miners in principles of hydraulics, which were applicable also to irrigation. These Spanish natives conducted water to their placer gold deposits in trenches, which they often carried by tunnel through the mountains. When they needed increased hydraulic pressure to wash out the copper and silver ores, they built reservoirs high up the valleys. Springs encountered in the mines were drained by the screw of Archimedes, the method used in ancient Egypt for raising water from the Nile to adjacent fields.[151] These same Turdetani cultivated the banks and islets of the Guadalquivir, and there maintained gardens and groves which delighted the eye.[152] They produced the finest olives for which irrigation was necessary.[153] This high state of tillage and a rainfall between 10 and 20 inches are irreconcilable facts except upon the theory of irrigation. It is a suggestive parallel that irrigation in central California utilized mining ditches, and spread in the wake of the prospectors; for fruits and vegetables were needed in the mining camps remote from settlements. After the paying dirt was exhausted and the camps were abandoned, the

old ditches continued to serve for irrigation along the foothills of the Sierras.[154]

IV. ANCIENT IRRIGATION LAWS

The wide distribution of irrigation in the Mediterranean region was reflected in an elaborate system of water rights which gradually developed out of custom and statute. The problem of such rights arose wherever a city like Athens or a village like Lamasbe undertook by communal effort to utilize and control the common water supply. The resulting laws showed local variations, but deviated little from certain big underlying principles. Finally in 550 A.D. they were codified in the legal Digests of Justinian, which embodied the water rights recognized throughout the Roman Empire; and in this form they reveal the importance of irrigation in ancient economic organization.

The law recognized that irrigation systems were very old. Hence specific water rights which went back beyond the memory of man were considered well founded without legal record, and could not be contested. Moreover, the phrase "ante-dating the memory of man" was broadly interpreted.[155]

Regarding Deflection of Water Streams.—The importance of water rights in this Mediterranean region is attested by the legal safeguards thrown around them. The law forbade artificial works altering the normal flow of a public or perennial river, or its diversion into a different channel from that which it occupied the previous summer, lest the riparian rights of the abutting estates be invaded. Rectification even for the purpose of strengthening the river banks was open to question, if it impaired riparian rights, though the law recognized the public utility of security from river floods.[156] But if a river shifted its course and thereby receded from its former position, water rights pertaining to the lands along its old channel were lost or at least interrupted till the river by deposition of alluvium gradually returned to its old course. Meanwhile the opposite bank approached by the fickle stream profited by the new contact and secured unexpected favors; for the whole stretch of the river was subject to water rights.[157]

Priority Rights.—More people could draw water from a public river than from an ordinary irrigation ditch; but all were compelled by law to respect the rights of their riparian neighbors or, if the stream were a narrow one, the rights of the estates on the opposite bank. The law provided in general that water taken

from a public river should be apportioned to the size of the respective riparian estates, except where one owner could prove a special right to a larger share.[158]

Right of Access to Water Course.—Rights to the use of an irrigation channel, a reservoir or spring comprised the right of access to the same, in order to clean and repair it and to connect the private pipe or conduit; for only thus could an efficient irrigation system be maintained.[159] As such water courses necessarily crossed private estates, the land along them or about them, in the case of reservoir or intake basin, was reserved from building, road-making or consecration for religious purposes, or any use that might interfere with the regular service of the water.[160]

Adjustment of Rival Claims—Such an irrigation channel was called a *rivus,* and all persons participating in its water rights were *rivales* or rivals,[161] a term which came to be applied to rivals in love by the old Roman comedies,—with peculiar appropriateness, for competition in water rights was keen, equity in them was jealously guarded, illicit draughts were common, and quarrels were frequent. The minuteness of the water laws and the analytical decisions of the praetors point to centuries of litigation in the effort to secure a fair distribution of the life-giving stream. Where several farms or farmers shared the use of a certain water supply, all had to be consulted before additional rights might be granted.[162] *Rivales* and servient estates were treated impartially. No one could do anything to the water course which might infringe on the rights of his associates. If a man was unjustly prevented by a "rival" or by the owner of the servient estate from drawing water, so that his meadow land or orchard or tree plantation was injured by the resulting drought, he could sue for damages.[163] Where part of an estate was sold, the water in the irrigation channel serving that estate was apportioned to the amount of land sold and retained without regard to the fertility of the land conveyed away or its need of water.[164]

The law *de rivis* applied when the water came from springs, even thermal springs.[165] Though cold water was preferable for irrigation, yet in certain localities where hot springs furnished the only water available, this law became operative, as in the Hierapolis basin of Greater Phrygia.[166] This was an old volcanic district in the upper Meander valley of Asia Minor,[167] where the rainfall was less than 20 inches (500 mm.) but where countless hot springs supplied the irrigation trenches and also the bath houses of Hierap-

olis, a famous Roman Spa perched on a high travertine terrace above the fertile plain. Today these waters still perform their beneficent task on peasant farm and orchard; but the ancient resort lies dead, wrapped in a winding sheet of travertine.[168]

Relating to Time Allotments.—Water rights varied greatly in time allotment for tapping aqueduct or reservoir. They might entitle a man to draw water all year round, or only in summer, or in certain months or certain days or certain hours. They were apparently regulated by the abundance of the supply, the seasonal need of irrigation, the size of the estate, and the purchasing power of the owner, though the latter point is only a matter of inference since no data are available. The law made a fundamental distinction between annual or daily water rights and summer water rights (*aqua cottidiana et aestiva*), a distinction based legally upon use but actually upon the reliability of the water supply. Only unfailing springs and streams which persisted through the summer drought could be subject to these two classes of rights. Daily water conferred annual use, available for both summer and winter, though its value in the cold rainy season was negligible except for watering cattle. Summer water, also derived from perennial sources, was drawn off only in summer and chiefly for irrigation. Such summer rights were determined by the purpose of the farmer and the nature of the district, which for climatic reasons required water only in the season between the vernal and autumnal equinox.[169] But the delivery of the water on March 25th enabled the farmer to turn it on his meadows and legume crops as soon as it was needed. However, restrictions of water in winter to estates entitled to *aqua cottidiana* certainly contributed to economy both as to use and leakage from the private conduits.

Summer rights were further restricted by allotment periods; and these differed greatly. From actual or suppositional cases cited by the praetors to elucidate the law, it appears that a grant might authorize a man to draw off water only in the daytime or only by night; or every day, or every other day (*tertio die*) or every fourth day (*quinto die*); or for one hour daily or on alternate hours daily, or for two or three hours on specified dates; or in alternate months or for one specified month during the summer. Moreover the water right was confined to the use of a certain aqueduct or reservoir or spring, and it was void for any other source. Withdrawal of water from any other source or at any other time than that specified involved forfeiture of the right. Forfeiture was also the

penalty for non-use during a period fixed by statute.[170] Nothing was left to the discretion of the user; everything was fixed by the terms of the contract.

The object of this rigid control was clearly to maintain a steady flow of the water for all entitled to its use, and hence to guard against a heavy over-draft that might decrease or stop the flow. For instance, the choice time for irrigation was night, when the plants were cool and loss of water by evaporation was low. But if all the sluices into the private conduits were flung wide open at ten P.M., the aqueduct might be empty for those drawing water at four A.M. To avoid such an injustice, where several persons had servitude rights in a channel from a spring on an adjoining estate, each man on his particular day opened his private conduit or pipe from the common canal, the parties following each other in order of distance from the source. If one man drew no water during the prescribed period, he forfeited his water right by non-use. Nor could he let one of his associates draw water in his place, for each man was limited to a separate right for his separate farm. However, if all the men were joint owners in a syndicate estate, the law was differently applied.[171] In that case, it assumed a wise distribution of the water for the benefit of the group, without question of conflicting rights.

Safeguards for individual rights were judiciously applied. If the water supply in a channel were abundant, several persons might receive water grants on said channel for the same days or the same hours, though the usual grant specified different days or different hours.[172] If two persons who had been accustomed to draw water separately from the same irrigation channel at certain hours, agreed to exchange their hours of use for their mutual convenience, they did not forfeit their water rights, despite the fact that neither had adhered to the hours specified in his grant.[173]

Coöperative Effort.—Irrigation works could be installed, as a rule, only by concerted effort. A peasant might use a spring or well on his farm for this purpose; but more often it was a city or rural district which resorted to this corporate enterprise for the common good. All citizens, by labor or taxes, contributed to the construction and maintenance of the irrigation works, all were entitled to a share of the benefit, and all learned a lesson in the sovereignty of law.

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THE CHILEANS AND THEIR GEOGRAPHIC ENVIRONMENT

R. H. Whitbeck

THE COUNTRY AND ITS PAST

Chile is a geographical unit. Only at its northern end is there any question as to the logical location of its boundaries. It might have been better if Argentina and Chile had been united into one country, for each is generously endowed with what the other lacks —minerals in Chile and agricultural land in the Argentine. But the massive wall of the Andes asserted itself and now permanently separates the two nations.

Chile is a distinctive country and a distinctive nation. In many ways it is a land of extremes—extreme in length and narrowness: extreme in climates, and in its activities peculiarly dominated by its climate:—its South deluged by excessive rainfall; its North virtually rainless; and its Central Valley mild in temperature and Mediterranean in type of rainfall. The Vale of Chile is the patio of the nation. The country's peculair shape, combined with its geographical situation, make the rainfall in various sections the dominating geographical factor in the economic life of the country.

Of all South American countries Chile is the most nearly self sufficient in the great range and variety of its natural resources. Moreover the Chilean people and the Chilean government stand out distinct from other West Coast countries.

We have come to associate with the Latin-American republics instability of government, the assassination of political opponents, the exile of officials, recurring revolutions, and default on foreign debts. In Chile we have a Latin American republic that operated continuously under one constitution (the oldest in South America) for nearly a hundred years (amended in 1925); that has had no military revolution within the memory of the oldest inhabitant, though it did have a short civil war in 1890, only a ripple in comparison with our own Civil War; a republic that has had only one president assassinated, in contrast with three in the United States; a country that for more than a hundred years shows no defaults on its foreign debts or any serious difficulties with foreign bankers or investors.[1] Even during the civil war with President Balmaceda, both of the militant groups, equally determined to preserve

[1]McQueen, C. A., *Principal Features of Chilean Finance;* Trade Inf. Bul. 162, p. 1, U. S. Dept. of Com. 1923.

the credit of the nation, tendered payment for interest due on the country's foreign obligations. Thus, in two particulars—maintenance of public credit and of constituted government—Chile has a notable record in Latin America.

THE CHILEAN PEOPLE

Chile has but 4,000,000 people, and only 1/20 of its land area is well suited to agriculture, yet the position of Chile in the councils of nations is not lower than third among the 21 Latin American republics; and, in military and naval prestige, it ranks nearly if not actually first. Its army has been trained under German officers and its navy under British officers. The Chileans are a military people, but their history does not show them to be particularly belligerent. Like other aggressive peoples when dealing with defeated weaker ones, they take what they think they need as they did after the war with Peru and Bolivia, and as the United States did after its war with Mexico.

Foreign observers comment on the snap, vigor, patriotism, and national spirit of the people. James Bryce, always a keen observer, speaks of them as the only Spanish American people who have shown any taste or talent for the sea.[2] "Prosperity and confidence are in the air" . . . he writes, "Men hurry to their business or their politics even as they do in western Europe or North America. Santiago is a real capital, the heart of a real nation. . . . Here are no loitering negroes or impassive Indians, for the population is all Chilean."[3]

Enoch says: "The Chileans must be regarded as one of the dominating personalities of the community of South American nations."[4]

Reclus says: "More Indian than European by descent . . . Chileans have a very marked personality amongst the South American populations."[5]

The Chileans are sometimes called "The Yankees of South America" and also "The English of South America."

INFLUENCE OF THE ARAUCANIANS

We may look for the causes of the strong qualities of the Chilean nation in three sources: (1) in the racial stock; (2) in the form

[2]Bryce, James, *South America*, p. 215, N. Y. 1912.

[3]Ibid., pp. 217-18.

[4]Enoch, C. Reginald, *The Republics of South and Central America*, p. 307, N. Y. 1913.

[5]Reclus, *The Earth and Its Inhabitants*, Vol. I, South America, pp. 447-8.

and character of the government; and (3) in the fundamental factors of the geographical environment.

First, as to the racial composition of the Chilean people. The Inca Empire extended Southward into Chile, but the Incas controlled only the arid north, where few people lived, and they did not exert any important influence upon the Chilean Indians, who were in some respects the most remarkable of all the tribes of either America. They possessed no such culture as did the Aztecs, the Mayas, or the Incas. They were savages, but they were the most fearless, intrepid, uncompromising fighters that the whites encountered in the New World. They fought the Spaniards to a standstill for more than 250 years. Spain hurled army after army against the fierce Araucanians only to find them unconquerable. It is said that the conquest of Chile cost Spain more blood and treasure than all the rest of America. Eventually the independence and the tribal holdings of the Indians had to be recognized (1655) and the Spaniards accepted the Bio Bio River, midway down the Central Valley in the forested land, as the northern boundary of the Araucanian domain.

After Chile gained her independence from Spain, the Araucanians still held out, and the *Frontera* remained at the northern margin of the heavily forested lands from which the whites could not dislodge the unyielding Indians. Only in 1881, after the white man's liquor and the white man's diseases had weakened the fierce spirit of the natives, did they yield and accept the rule of the Chilean government. Most of the Spaniards who came to South America were men, and Indian women became the mothers of the children born during the period of the Spanish settlement. In Chile these were the Araucanian women. Practically all of the colonial stock of Chile, founders of the old families, was of mixed Spanish and Araucanian blood.

Geographical environment, including climate, must always be an important influence in the shaping of racial character, provided the race in question lives long in the same environment. Yet, no one can say how much the geographical environment had to do with the making of Araucanian character. These Indians lived in a region of Mediterranean and transition climate, in the temperate zone. No tropical tribes ever manifested the valor, steadfastness, and tenacity of these intermediate zone Indians. They defended a narrow ribbon of land, guarded by the sea on one side and by the great Andes barrier on the other, and backed by dense forests. Their flanks could not be turned. They could not be sur-

rounded. Nature fought with them and contributed to their successful resistance; and their successful resistance renewed their valor and self-confidence. It is not difficult to believe that geographical influences underlie the character and military success of the Araucanians, but just how potent those influences were no one can say.

Certain it is that the liberal infusion of Araucanian blood in the present Chilean population accounts for some of their characteristic traits. Moreover, there is considerable Basque blood in the Chileans, and at least one writer asserts that the immigrants from the north of Spain to Chile included more than the usual amount of Gothic blood. So much for the racial aspect of the Chilean nation.

STRONG GOVERNMENT BUT NEGLECTED WORKERS

A second notable characteristic is the stability of the Chilean government, which is extremely centralized; the governors of the provinces are appointed by the president of the republic and ministers are now responsible to the president alone. Suffrage is restricted by literacy and property qualifications, and the voting population is relatively small. The government has been more an aristocracy than a republic, for the group of powerful families who hold the greater part of the land have usually ruled the country. This rule has given Chile stability and credit, but, like the Diaz regime in Mexico, it has done little to improve the wretched condition of the working class, and particularly of the agricultural laborers. Wages are pitifully small, and working men's homes are usually hovels. In the south of Chile, the farm laborer works from sunrise to sunset for 25 to 50 cents a day, in money, plus a little piece of land and a hut. Skilled mechanics receive $1.00 to $1.50 per day. It is difficult for the workers to obtain land. They are poverty stricken and the land is largely held in great estates by aristocratic families. One-half of one per cent of the population owns 59 per cent of the land, and opposes the taxation of real property for roads and country schools, if they are to be paid for by local taxation.

THE FAR SOUTH

The economic life of every part of the country is closely bound up with its distinctive climate, surface features, location, and resources. Chile is a land of tremendously accentuated natural features and of great and varied mineral wealth.

Of all the climatic features, rainfall is much the most significant. The economic activities of the nation are singularly related to the rainfall regimen that prevails in the various sections. The extreme southern quarter, lying in the path of the westerlies, receives almost daily downpours of rain. The ground is perpetually water soaked. Roads and even trails are scarcely passable on the densely-forested mountain slopes or along the boggy valley bottoms. A 300-mile section of mountains between latitudes 47 and 52 receives heavy snowfall, has scores of living glaciers, and is largely unoccupied. Still farther south the heavy forests and the snow fields give way to extensive sheep pastures where incorporated companies—Chilean and British—raise heavy-fleeced flocks numbering many millions of sheep. In seasons of favorable weather the industry is extremely profitable, but occasionally tens of thousands of sheep perish from cold and starvation. Wool and frozen meat from this region constitute nearly 40 per cent of agricultural and pastoral exports of Chile. Both the forest industries and the sheep industry are direct responses to the accentuated climatic features of this remote land.

IRRIGATION, AGRICULTURE, AND FARMING METHODS

Of Chile's 2600 miles of length, only the Central Valley—600 miles long and 25 miles broad—has geographic conditions suited to agriculture. The valley floor is by no means flat, as most of the land is in the Valley of California, but is crossed by mountain spurs and dotted with groups of hills. The southern half of the Valley, lying in the westerly wind belt, has rainfall in summer as well as in winter, but the northern half of the Valley has a Mediterranean climate with little rainfall, and that in the winter, making summer irrigation necessary. While irrigation is the salvation of agriculture in this the most delightful part of Chile, the amount of land actually irrigated is small (2,800,000 acres). It is especially a region of vineyards, and wine is one of the leading Chilean products. The northern part of the Valley is another Southern California, which it closely resembles in climate and products. Wheat is more important in Chile than in California; it occupies more land than all other Chilean crops combined and provides a surplus for export. In agriculture, as in most other Chilean industries, precipitation is the governing factor.

So far as the chief occupation of the people goes, Chile is an agricultural country, for the greater part of the people still live and work on the land. Small as the food-producing area is, it

equals that of Japan, whose crops provide food for nearly 50,-000,000 people. Farming methods in Chile like rural conditions generally, are extremely backward, but less so than they are in Bolivia or Peru. For example, much threshing of grain is still done by driving horses or cattle around on the straw. Oxen are the prevalent farm animals. While Argentina has one horse for each person in the country, Chile has only one for each ten persons. The inefficiency of farm laborers is shown by the fact that, on an average, one agricultural worker is employed for each 12 acres of crops grown. This fact is still more impressive when it is remembered that more than half of the cropped land is devoted to wheat, a grain requiring relatively little labor, while only one-eighth is devoted to grapes, which require much labor. Food exports and imports nearly balance, so it may be said that Chilean agriculture merely feeds the 4,000,000 Chilean people. Meat- and milk-animals are far less important than they are in the River Plate lands beyond the Andes.

The outstanding facts about the agriculture of Chile are (1) the extremely small fraction of the land that is cultivated—between 1 and 2 per cent—due mainly to climatic and topographic handicaps; (2) the almost complete restriction of agriculture to the Central Valley, in half of which irrigation is required; (3) the backwardness of farming methods, the lack of good roads, the very low wages paid, and the wretched living conditions of the agricultural laborers, mostly Indians and mestizos; (4) the prevalence of great landed estates controlled by a few hundred families that have long constituted the ruling class of Chile, but whose sway is being vigoroussly challenged.

THE GREAT MINERAL WEALTH

The large mineral production of Chile is well known. It exceeded in value the mineral output of all the other countries of South America combined until 1927, when the production of petroleum in Venezuela became very large. Sodium nitrate ordinarily provides half of the total value of the mineral products of Chile. But, it may be noted in passing, the value of all the minerals annually produced in South America is less than half that of Pennsylvania alone. The ratio is 500 million dollars for South America, 1,000 million for Pennsylvania.

A second fact relating to mineral production in Chile is that 9/10 of the value of all exports consists of minerals, mainly nitrate and copper, and that over one-half of the value of the minerals is

produced by foreign capital, American investments being largest, notably in copper.

In a good nitrate year, from 1/4 to 1/2 of the national revenues came from the export tax of $12.00 a ton on nitrates. The nation's financial dependence upon these revenues has given the Chileans much concern, for all aspects of the nitrate industry have been troubled with uncertainty, for several years. In 1928 the Chilean government guaranteed the nitrate producers about $41.00 a ton, and also fixed a selling price abroad which practically refunds the export tax to the producers. This important step should greatly benefit the industry and enable it to compete successfully with synthetic nitrate. The nitrate production in 1928 (3,000,000 tons) was about the highest ever attained, and only 70 plants were in operation. The new and much more efficient methods now being employed by the Guggenheim company should also greatly benefit the industry.

The complete dependence of these readily-soluble nitrates upon the arid climate is a further instance of the dominating influence of rainfall, or its absence, in the economic life of Chile. The origin of the nitrate beds is still a matter of doubt, but that they owe their deposition, and still more their preservation, to the extremely arid climate is fully recognized.

Chile is the only South American country that mines enough coal to be worth mentioning, although the annual output is now only about 1½ million tons. The quality is low, and it is unsuited to coking. Before the opening of the Panama Canal, steamships, coming for nitrate, bought Chilean coal, poor as it was, but that trade has practically ceased and, moreover, fuel oil is replacing coal in this part of the world as it is elsewhere.

Chile is also the only South American country that mines iron ore to any extent. This is done by a subsidiary of the Bethlehem Steel Corporation and the ore is transported in a fleet of specially-built ships by way of the Panama Canal to the company's smelters on the water front near Baltimore. Owing to the fact that Panama Canal tolls are based upon cubic capacity of the ship and not upon the weight of the cargo, the toll on a ton of ore may be as low as 25 cents. The quantity of iron ore shipped varies between one and two million tons a year.

American copper companies operate three copper camps of great size in Chile, and give that country second rank among the copper producers.[6] The northernmost camp at Chuquicamata, is in an absolute desert. It employs more than 15,000 persons, is a model

camp, and is one of the largest in the world. Here again the arid climate enters as a factor for the greater part of the vast copper ore deposits of this region are soluble oxides that have been preserved by the dryness of the region. This one open-pit mine is sending out more than 300,000,000 pounds of pure electrolitic copper yearly, and the common shares of the company are selling at nearly four times par (1929).

The Braden Copper Company's mines in the high Andes south of Santiago are also producing on a vast scale, but below that of Chuquicamata. The most recent of the great American copper properties to be brought into production is that of the Andes Copper Company at Potrerillos in the arid northern section of Chile. All of these great ore bodies are of low grade (usually under 2 per cent), but they are mined and treated on a vast scale by the most efficient methods, and are proving to be highly profitable to their owners.

WELL SUITED TO MANUFACTURING

In addition to its coal for mechanical power, Chile has a number of short, swift rivers that rise in the snow fields of the Andes. There are numerous sites at which hydroelectric power is available, and part of which is already developed. The main line of railway from Valparaiso to Santiago and Los Andes is already electrified.

Considering what a small country like Japan has already achieved, and realizing that Chile has fully as much food-producing land, has much greater mineral wealth, better forests and greater variety of raw materials for manufacturing, it is evident that the country may justly aspire to an industrial future. Upon this it is already launched with 3,000 manufacturing plants making yearly 200 million dollars' worth of products under the protection of a high tariff. It is fitted to become the most nearly self-sufficient nation in Latin America, unless Giant Brazil be the exception.

Chile has its own national problems—political, social and economic—and they are serious ones, but the natural wealth within the country, the genius of the people and the record of the past give promise that those problems will be courageously met and solved.

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[6]Copper production in Chile in 1928 was over 600,000,000 pounds, or six times the output in 1913.

THE POLAR EQUAL AREA*

A NEW PROJECTION FOR THE WORLD MAP

J. Paul Goode

The need of an equal area projection for the world map, which would show true space relations across the North Pole, and for all the continental lobes across the equator as well, was the necessity which was the mother of an invention of a new projection, here presented. Last July Mr. George Finlay Simmons, curator in ornithology in the Natural History Museum of Cleveland, Ohio, wrote me asking for such a projection. He is studying the hunting falcons. These birds, with an apparent center of dispersal in western Siberia, show progressive differentiation covering the lands about the Arctic Ocean, and along lines of dispersal from these high latitudes over all the continental lobes to the south, and across the equator to the limits of the land.

Reluctantly I answered him that there was no such projection. There are projections which show true space relations across the North Pole; and all the ordinary projections presenting the earth in the equatorial aspect would serve to show space relations across the equator, but no one projection would do both. The need, however, suggested the following solution.

The principle used is an old one, first enunciated, so far as can be found, by Jean Werner of Nürnberg, in 1514 A.D.[1] Werner was translating and reviewing the latest "Ptolemy," as general map collections had been called for fifteen hundred years, and remarked that it was unnecessary to use the crude device of Ptolemy for a world map, since the problem of deploying the surface of the Globe in an equal area projection could be done in three different ways. The first of these he developed, and it still bears his name. The projection is arbitrary or conventional; it is strictly equal area; and it proves to be one of the most useful projections we have for geographic maps.

Werner thought only of presenting the earth's surface entire. And when his first idea was developed it provided a map of the

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*Read before the Association of American Geographers. New York, Dec. 28, 1928.

[1]Germain, A., *Traité des Projections Geographiques.* Paris, E. Thunot, (1865)?

earth's surface in a very interesting heart shaped figure, with a sharp sinus down to the North Pole, and a sharp point at the South Pole. But though the angles, and therefore shapes, are perfect along the mid meridian, the angles become very acute toward the margin of the map, and therefore shapes are so sadly deformed as to make the projection of no value for map purposes, *as a world map*. But it was very superficial judgment to condemn it on this basis alone. Yet, being condemned it dropped out of consideration through the centuries.

The psychology involved is interesting. There is a Spanish proverb which expresses it: "Give a dog a bad name and hang him." The English have another saying which illustrates how difficult it is to rise above an evil reputation: "We have the name, we may as well have the game." None of the writers on projections gave it much consideration. Germain found some virtue in it, saying (p. 98), "Cette projection serait donç tout au plus bonne pour les regions voisine du pole." But as late as 1882 our most distinguished authority on projections, Thomas Craig,[2] gives it a scant inch of space, saying for his last sentence (p. 75), "This projection is not of enough importance to spend any time in obtaining any of the formulas connected with it."

We need not at this time be too severe on Craig or other writers on projections. They have all of them been mathematicians first, and interested in projections mostly as intriguing problems to be solved. This projection is too simple to furnish grist for their mill.

Now a geographer comes to a projection with a different point of view. He is interested in it primarily as a means of providing a map for some definite use. Whether the making of it calls for much mathematics or none, is a matter of no consequence to him. And it will be quite pertinent at this point to inquire what are the prime requisites in a projection for use in geography. And the answer is not far to seek.

The most important virtue a projection may have, is that it provide an *equal area* map. That is, a map in which any square inch represents the same number of square miles of the earth's surface, as any other square inch in the map. It is a pedagogical crime to enter areal distribution of any sort, upon a map like the evil Mercator, which has not the equal area quality.

[2]Craig, Thomas, *A Treatise on Projections;* quarto, pp. 247. U. S. C. & G. S.; Washington, 1882.

Next in importance to the equal area quality, is that the map provide the best possible *shapes* to continents and other surface features. And that projection provides best shapes which departs least from the truth of angles and scale. On the globe all meridians cross all parallels of latitude at right angles. The ideal projection departs as little as possible from this right angle quality. Conic and cylindrical projections provide absolute truth of angle, but may provide monstrosities as maps, because of varying scale.

Now to look more intelligently at the projection proposed by Werner, it will be observed that angles, and scale and therefore shapes, are true along the mid meridian from the North Pole to the South Pole. And in high latitudes about the center of projection, there is surprisingly little departure from the truth of angle, even in a wide range of longitude. It was the discovery of these fine virtues which led the author in 1910 to choose this projection for his wall map of North America,[3] in spite of the evil reputation which had been unjustly saddled upon it from the beginning. The result is a map of North America which has strictly the equal area quality, and which in scale, angle, and shape compares favorably with the best result any projection can give.

So when the demand came for a projection which should deploy all the continental masses so as to keep true space relations across the North Pole, and on each continental lobe across the equator as well,—the virtues of this old discredited projection came to mind, and to it was brought at once the device of interruption of the grill of latitudes and longitudes, which has proved so valuable to the geographer, as applied already to other projections.[4]

This device interrupts the grill so as to give each continent or ocean, a mid meridian of its own, thus assuring it of the best possible shape the projection affords. Applied to Werner's device, a wonderful result follows.

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[3]Goode, J. Paul. Wall map of North America; 46 x 66 inches. Chicago: Rand, McNally & Co.

[4](a) Interrupted Sinusoidal Equal Area, by J. Paul Goode. Copyrighted, University of Chicago, 1917.

(b) Interrupted Homolographic Equal Area, by J. Paul Goode. Copyrighted, University of Chicago, 1918.

(c) Homolosine, Equal Area, by J. Paul Goode. Copyrighted, University of Chicago, 1923.

FIG. 1. A POLAR EQUAL AREA PROJECTION[1]

For the continents the North Pole is chosen as the center of construction. The three great continental lobes are deployed

[1]This projection is copyrighted by the University of Chicago, 1928, and published as a base map by the University of Chicago Press.

radially from the North Pole. Each continental lobe is given a mid meridian of its own, part of a radius from the North Pole. On each mid meridian true distances are pointed off for the parallels of latitude. Through these points, with radii from the North Pole, arcs of circles are struck for the parallels of latitude. On these parallels true distances are pointed off from the mid meridian for the position of the meridians. Through homologous points on the parallels, free curves are drawn for the meridians. It follows, since the parallels and the meridians are their true distance apart, that the projection has the equal area quality. It follows also that every point in the map is shown in its true distance from the North Pole.

Since this particular form of this projection is devised to show land distributions, the lands are given the best shapes possible. So an extension of the idea of a mid meridian for the continent is introduced. That is, the mid meridian is allowed to migrate freely on any parallel of latitude to a position which will keep it in the middle of the land at that latitude. This provides surprisingly good shapes for the continents. North America is just about as good as any projection can give singly. South America is good, though "dished" a little on its northern shore because all the parallels of latitude are concave northward. Eurasia, in spite of its 190° spread of longitude, is almost as perfect as any projection can give it separately. The same is true of the East Indies and Australia. Africa, though good, suffers a little in shape by having all its parallels concave to the north.

It will be observed that on the land areas the departure from right-angularity is so slight, that a scale of miles can be used quite as well as upon any ordinary continental map. This is a rare quality in a world map—a great virtue.

The projection lends itself to all manner of areal distributions: in geology, paleontology, meteorology, climatology, botany, zoology, anthropology, and ethnology—where continental space relationship is important.

Where ocean unity is more important than continental unity, the projection lends itself quite as readily to the deployment of the oceans radially from the South Pole.

SEQUENT OCCUPANCE

DERWENT WHITTLESEY

Human occupance of area, like other biotic phenomena, carries within itself the seed of its own transformation. Some examples of this principle are everyday commonplaces. The American farmer, inaugurating a stage of occupance by plowing and planting virgin soil, sets in motion agents which at once begin subtly or grossly to alter the suitability of his land for crops; in extreme cases the ground deteriorates to a point where it must be converted into pasture or forest, or even abandoned; when either of these events occurs, human occupance of that area has entered upon a new stage. To take an example from urban life: the normal increase in population of a wisely located and hence successful urban area in time forces the resident population to remove to a zone some distance from the center, which thenceforth is occupied in a wholly new fashion. A political instance of the principle appears in the unification of a large and diverse area under a single system of government; despite advantages derived from solidarity, the inhabitants of marginal districts feel the application of many of the laws as hardships; ultimately the political unit breaks up or becomes a federation of loosely connected entities with a large degree of local autonomy.

Because of its obedience to rule analogous to that governing human organisms, the study of human occupance of area rests on secure foundations if its dynamic character is recognized and adequately accounted for. Spatial extent is always taken for granted as implicit in the geographic craft. In fact the distribution of people and of their activities over the surface of an earth of varied forms, conditions, and resources, is conceded to be the major premise of anthropogeography, human geography, or chorology, as it is variously called. These spatial concepts remain purely descriptive, however, unless they are treated dynamically, i.e.. unless the time factor is cognized. The view of geography as a succssion of stages of human occupance establishes the genetics of each stage in terms of its predecessor.

The significance of genetic treatment can be illustrated by reference to a specific area, a district of some fifteen square miles in Northern New England. This small region may be described today as a massif of high hills, mantled in bouldery podsol soil,

deeply buried in snow in winter and abundantly watered with frequent summer rains; a land of long cold winters and cool summers with only occasional short periods of hot days, covered with a tangle of pioneer, deciduous and coniferous, second-growth forest, in parts of which calves are allowed to graze, and penetrated by a few grass-grown lanes. Greater specification as to degree of slope, depth and character of soil, amount and distribution of moisture and heat, species and measurements of trees, and length, width, and directions of lanes would make the description more exact but would not alter its exclusively descriptive character. But if this description be posed in sequence with preceding modes of human occupance and with a suggestion of the probable succeeding mode, the descriptive distribution takes on the character of a genetic correlation.

The present stage of human occupance in this New England region was immediately preceded by a thoroughgoing subjection of the land to farming. As attested by numerous walls and foundations of boulders, and by written record, roads were numerous and dotted with farmsteads. All the gentler slopes were used as plow land, somewhat sharper gradients being cleared of forest for cattle and sheep pasture, and only the steep, ledgey, or infertile land was left in timber, some of which was selectively cleared to procure maple bush for sugar, the rest serving as a reservoir for locally consumed saw timber, fence posts, gate bars, and fuel. A village occupied a convenient "corners," and the population was largely self-sufficing, procuring from the outside only luxuries and some utensils and implements, purchased with the small available surplus of wool, hides, and maple sugar. Preceding this farming stage of occupance, the region had been virgin mixed forest and its human denizens a few Indians who lived a migrant life, depending chiefly on collecting from the forest berries, fuel, and game. On this background of the present-day occupance the future can be forecast with reasonable certainty as an occupance by forests once more, but cut periodically at the will of non-resident owners for wood-pulp or possibly for lumber.

In this New England district each generation of human occupance is linked to its forbear and to its offspring, and each exhibits an individuality expressive of mutations in some elements of its natural and cultural characteristics. Moreover, the life history of each discloses the inevitability of the transformation from stage to stage.

The period of collecting maintained itself as long as exploitation did not become destructive, but when white hunters and fur trappers, with their imported weapons, were added to primitive Indian "collectors" from the forest, the aboriginal resources failed, and destruction of the forest itself ushered in the period of farming. In its turn farming succumbed to decreasing yields, always rapid on podsol soils. The close of this stage of occupance might have been postponed by the construction of improved transportation (railroads) and consequent modification from subsistence to interdependent agriculture, had not railroads at the same time opened to settlement and to competition the far more favored farm lands of the Middle West. Left to itself, the land promptly began to recreate forest, which has again become the key to the region's chorology, but this time to be utilized in conformity to the present-day pattern of human occupance in North America—as an export crop in the form of pulp, paper, or lumber.

Not only does the recognition of sequent occupance place the current stage in its proper relation to antecedents and to successors; it throws it into true perspective. In the New England illustration, the present era of idle land and renascent forest, with some incidental grazing, is seen to represent, not a distinct mode of human occupance, but a transition period, in which vestiges of the farming epoch linger on in the casual grazing of the margins, and in which an earnest of the era to come is offered by the constantly meliorating tree growth, although at the moment there is no saw timber and little pulpwood.

The analogy between sequent occupance in chorology and plant succession in botany will be apparent to all. But the botanist's problem is the less intricate, because he is dealing with a single subject, plant associations, and the chief agents of their transformation are but three—climatic, edaphic, and economic; whereas the chorologist centers his attention on the human occupance of areas, and so must take account of changes in any of the complex elements of natural environment, and in the equally complex cultural forms.

Such of these alterations as evolve from the inherent character of a particular mode of occupance follow a normal pattern and at length usher in a new and consequent mode of occupance. Strictly speaking, normal sequences are rare, perhaps only ideal, because extraneous forces are likely to interfere with the normal course, altering either its direction or rate, or both. These may be so-called acts of God, whereby one or another element of the

natural complex becomes abruptly and profoundly modified. Such are severe earthquakes, windstorms, tidal waves, floods, volcanic eruptions, landslides, insect or other biological pests, pestilence, and the like. Interruptions of the cultural order engendered by man occur even more commonly: shifts in political boundaries, revolutions, or often mere enactment of laws; movements of population which carry with them mores and attitudes novel to their new habitat, or create social friction; the introduction of new technology; changes in means of communication which alter physical and mental contact with outside regions; all these are capable of breaking or knotting the thread of sequent occupance. When once the new forces begin to operate, however, the dynamic march is resumed, but according to new orders of the day. In these phenomena of interruption appears an analogy to the physiographic cycle of erosion, although clearly neither the subject matter nor the operative forces are the same, and the concepts of youth, maturity, and old age, when applied to the dynamic course of human occupance of area, are likely to place it in a false light.

It must be admitted that the student of sequent occupance of area is beset with an intricate problem. Nevertheless, the complexity which springs from the infinite interplay of many elements of the natural and the cultural landscape is common to all chorologic study. In fact the concept of sequent occupance, when a sufficient number of studies have been made, should point the way to simplification impossible under the purely descriptive discipline. Description becomes more elaborate with every step in the direction of exact statement and detailed observation, whereas all indications suggest the probability that in nature relatively few sequence patterns have ever existed. Their recognition therefore holds the hope of a system of classification despaired of so long as chorology remains merely the multiplication of observations and their presentation.

Such a classification, moreover, being evolved from the inherent traits of the subject matter of chorology, is structurally firm and homogeneous. Hence the worker in the subject is relieved from the taxing and unsatisfactory requirement of classifying his findings according to a foreign discipline, be it geologic, economic, or whatever—a compulsion very disquieting to many who have felt either its illogic or its stupendous difficulty. Instead, the continuous but varicolored woof of human life is woven with the firm but not uniform warp of areas into a strong yet supple texture, pleasingly varied but always orderly in pattern.